1998

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THE ANALYSIS OF RECIPROCATING COMPRESSOR SUCTION PART BY USING FLOW VISUALIZATION TECHNIQUES AND DIGITAL IMAGE PROCESSING

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ABSTARCT

The applicable compressor designs are those in which the suction gas from the evaporator is dumped into the compressor shell, and is then drawn through a muffler into the compressor. In the reciprocating compressor having close distance between suction pipe and suction muffler, the greater part of refrigerant from suction pipe is directly sucked into suction muffler, but a part of refrigerant leaks into the void space in hermetic shell and contacts to cylinder, motor or other high temperature parts. The temperature rise of refrigerant due to this leakage decreases the efficiency of a compressor. Therefore the efficiency of a compressor increases with the amount of leakage decreases. To estimate the flow rate of the gas that is sucked directly to the suction muffler, we have proposed a technique. To study the flow pattern of the suction gas in transit between the suction pipe outlet and the suction muffler inlet, we have proposed a technique of concentration measurement through digital image processing. The experiment of mass transfer in a suction gas flow has implied the measurement of distribution of tracer concentration.

INTRODUCTION

This paper deals with the hermetically sealed refrigeration compressors. More particularly, it concerns the design of the suction gas flow passages between the suction pipe outlet and the suction muffler inlet. For this design, only part of the suction gas entering the shell goes directly into the suction muffler inlet. The remainder is dumped into inside the shell, and is superheated by the heat sources, such as motor and moving parts. Theoretical estimates show that for the small refrigeration compressor considered here, a 10 ℃ increase in suction gas temperature results in approximately a 3 percents decrease in compressor efficiency. Theoretically, well insulated, direct connection between the suction pipe outlet and the suction muffler inlet would be the most efficient design. But direct connection include separating problems, such as the refrigeration oil from the refrigerant, noise increasing problem by noise propagation and reliability problem on the suction pipe and suction muffler by vibration. So, we wish the suction gas is sucked to the suction muffler with indirect suction design and as possible as, with low temperature.[1]

MEASUREMENT OF DIRECT-SUCTION RATIO

As stated previously, the ratio of refrigerant sucked directly into the suction muffler to the total refrigerant introduced from suction pipe is one of the most important factors which control compressor performance. The (DSR)direct-suction ratio (δ)is defined by the following equation

δ = Directly sucked refrigerant into the suction muffler / Total refrigerant introduced from suction pipe

In this the paper, technique of concentration measurement through digital image processing[2] is adopted to determine DSR value. By ignoring flow rate pulsation due to piston motion and assuming steady flow with the flow rate of $\overline{Q}$, the transport of refrigerant around the muffler is modified by the conceptual model shown in Fig.1.

When the variation of tracer concentration in the shell is signified by C_s, and is represented by following equations.

$$(dC_s / dt) = -\alpha C_s) \tag{1}$$

$$\alpha \equiv (1-\delta)\overline{Q} / V_s$$

$$\therefore C_s = C_{s0} \exp(-\alpha t) \tag{2}$$

Therefore, by measuring the variation of C_s with time, α or δ can be calculated from the shape of the variation curve.

MEASUREMENT OF TRACER CONCENTRATION DISTRIBUTION THROUGH DIGITAL IMAGE PROCESSING

We consider the situation that a model chamber filled with visible tracers is illuminated by a light sheet, visualized images are recorded on VTR, and the images are analyzed afterward by using an image processor.

Since the ray intensity scattered by tracer particles to the camera direction is proportional to tracer concentration provided the ray extinction due to tracer particles can be ignored , the strength of the incident ray to the camera lens is also proportional to tracer concentration. But the gray level output of each pixel on a digital image is not proportional to the strength of incident ray in general. The relation between them depends on the characteristics of the camera, lens, VTR and image processor used in a measurement. Therefore the calibration curve between gray level output and the strength of incident ray has to be obtained under the same condition as the measurement. Here a transparent vessel filled with water containing milk is illuminated with the Ar-laser light sheet which is used in the measurement, and its image is recorded on VTR through optical filters inserted on the camera lens. The strength of incident ray ,I, varies following to the equation.

$$I = I_0 \exp(-nr) \tag{3}$$

Here n and r are the number of filters and the optical decay rate of a filter, respectively. An example of calibration curve is shown in Fig. 2., in which $I_{\max}$ represents the maximum value of I and g, $g_{\max}$ and g_0 represent gray level, $g|_{I=0}$ and $g|_{I=I_{\max}}$, respectively.

APPARATUS AND METHOD OF EXPERIMENT

The visualized zone is the plane between the suction muffler and the shell. This plane is illuminated with the Ar-laser light sheet, and the visualized images are recorded on VTR. The schematic of test equipment is shown in Fig. 3. And Fig. 4 shows the schematic diagram of experimental set up.

The procedure is as follow :

(a) After the void in the shell is filled with tracer particles, the compressor operation is started by turning on the switch. At the same time, the ventilation of the shell by room air ($C_p = 0$) is initiated.

(b) The LED placed in the visualized zone also turns on by the switch to give the record of initiation time on the image.

(c) One measurement is finished when the concentration decreases to be sufficiently low.

As visible tracers, oil mist particles are generated from the atomizer by using a diaphragm air pump. DOP oil which is used widely in aerosol technology is used. An electric heater within the atomizer controls the tracer concentration by adjusting oil temperature.

RESULTS AND DISCUSSION

The DSR value depends on the shape of the suction pipe. Fig. 5 represents some examples of concentration variation with time for a part of experiments. Relatively fast ventilation observed indicates the significant amount of spilled flow.

The DSR values for a type of suction pipes at different position relative to the suction muffler are shown in Fig. 6. The misalignment of the suction pipe brings significant decrease of DSR value.

CONCUSIONS

From flow visualization and image processing of the flow patterns in a compressor the following conclusions are drawn :

1) The technique of concentration measurement through digital image processing is useful for the design of the suction gas flow passage in compressors.

2) The misalignment of the suction pipe brings significant amount of spilled flow. It is important to select the adequate position of suction pipe.

REFERENCES

1) I. S. Lee and K.Y. Hong : Flow visualization applied to oil flow of suction muffler of a small refrigeration compressor, Proceeding of the 23th VSJ Symposium , 1995, pp. 343 ~ 346.

2) A. Kaga, Y. Inoue and K. Yamaguchi : Three-dimensional concentration measurement in a ventilated room model through digital image processing, Proceeding of the ISFV '92, 1992, pp. 369 ~ 473.

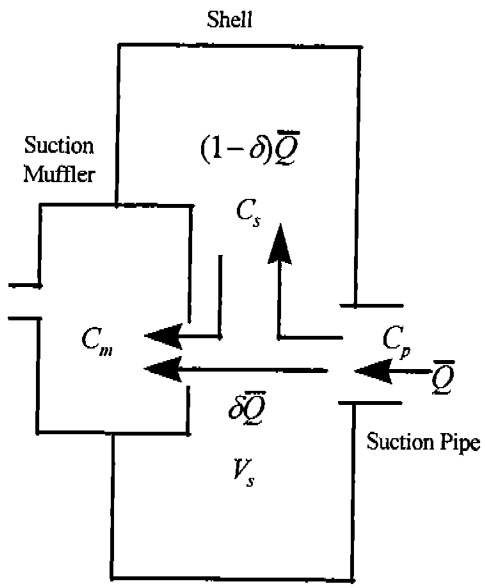

Fig. 1 Conceptual Model of DSR

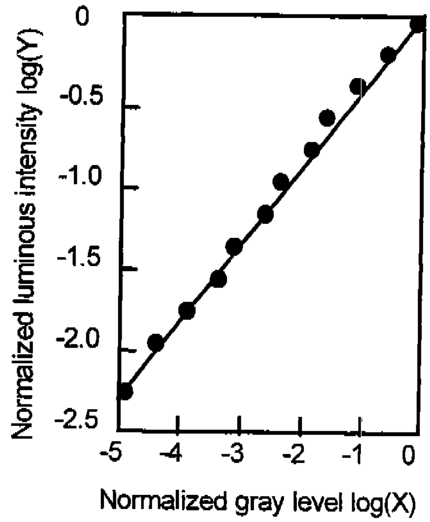

Fig. 2 Calibration Curve between Gray Level and Incident Ray

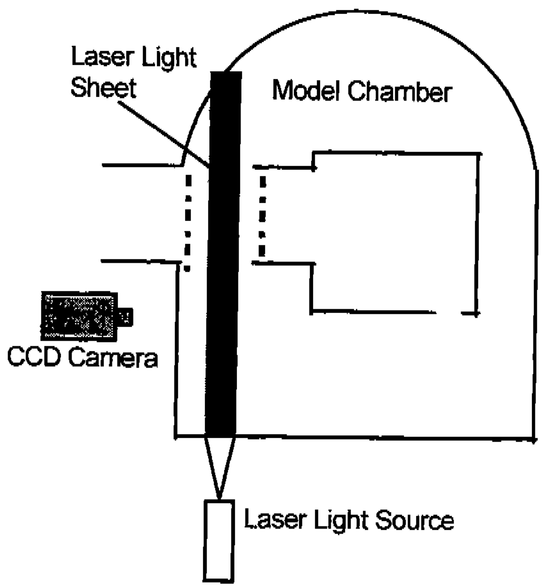

Fig. 3 Schematic of Test Equipment

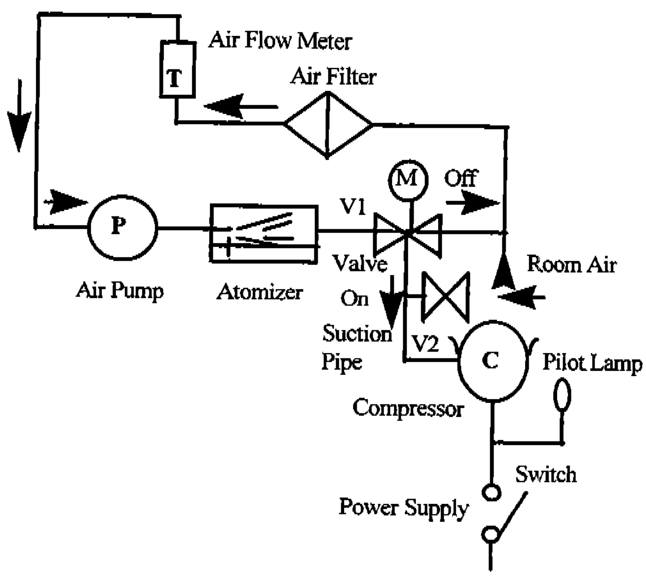

Fig. 4 Schematic Diagram of Experimental Set Up

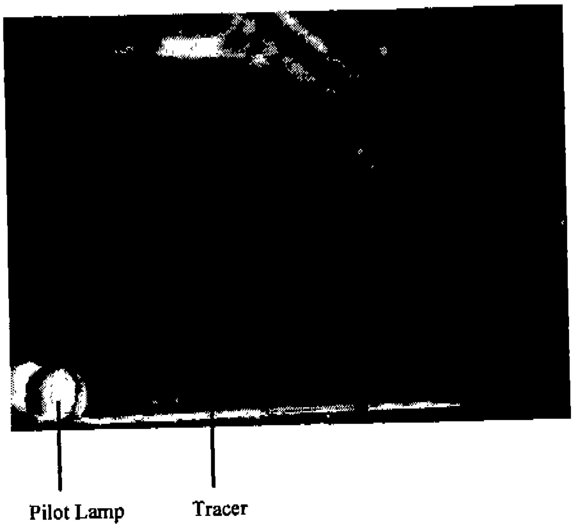

Fig. 5 Example of Concentration Measurement

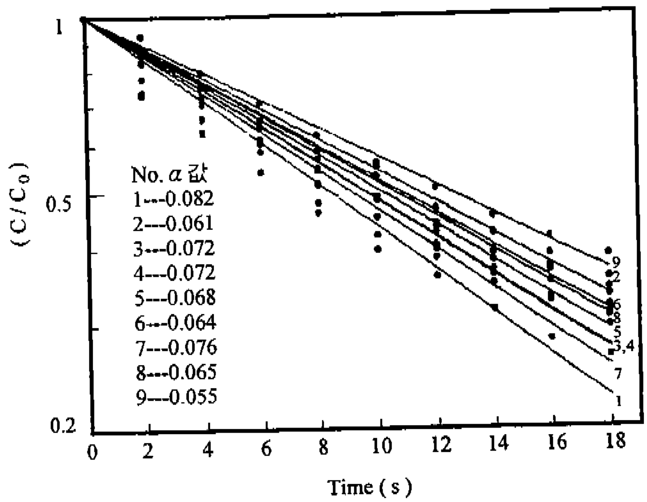

Fig. 6 Examples of concentration distribution decrease(B Type)